Report for 2003GU20B: Groundwater Infiltration and Recharge in the Northern Guam Lens Aquifer as a Function of Spatial and Temporal Distribution of Rainfall

There are no reported publications resulting from this project.

Report Follows

PROJECT SYNOPSIS REPORT

Project Title: Groundwater Infiltration and Recharge in the Northern Guam Lens Aquifer as a Function of Spatial and Temporal Distribution of Rainfall

Problem and Research Objectives

Groundwater is the most important source of Guam's drinking water. Nearly 40 million gallons per day (mgd) are currently extracted from the thin lens-shaped body of fresh water that floats atop the seawater that permeates the limestone beneath it. Current environmental regulations on water production are based on the sustainable yield estimates from the 1982 Northern Guam Lens Study (CDM, 1982), which totaled to 59 mgd. Later estimates by J.F. Mink (Mink, 1991), based on well responses predicted by a computer model totaled to 70-80 mgd. Accurate assessment of the sustainable yield of the aquifer is crucial for effective planning and management of Guam's groundwater resources. The sustainable limit for withdrawal of groundwater on Guam is the amount that can be withdrawn by current technology without inducing salt-water intrusion into the wells. Pumping rates and well density must therefore be limited to amounts that do not cause salt water beneath the lens intercept the intakes of production wells. On the other hand, over-conservative limits to water production will constrain economic development by inhibiting development of new production and driving up costs.

Guam is characterized by one of the highest levels of rainfall variability in the world, with the highest annual rainfall nearly three times the lowest rainfall. This makes the region susceptible to droughts and floods, in addition to the large typhoon risk that threatens the island. This high rainfall variability directly affects ground and surface water supplies, water quality, erosion, pollution from run-off, and local flooding. Rainfall on Guam also has extreme short-term temporal and spatial variations depending upon large-scale weather patterns. When Guam is within the doldrum trough of summer, local thunderstorms may deposit upwards of 100 mm in one hour over an area as small as a few square kilometers, while the rest of the island gets little or no rainfall. When the island is within strong monsoonal southwest wind flow, or in the periphery of a tropical cyclone, similar peak hourly rain rates are possible, but the spatial distribution is larger. Nearly every location on the island receives a substantial amount of rain (although spatial variations may still be large – for example: a peak 24 hour amount of 200 mm may occur over the central part of the island with minima of 100 mm at other island locations). The direct passage of the core of a tropical cyclone over the island is responsible for all historical 24-hour rainfall totals of more than 250 mm. Tropical cyclone core rainfall has a larger spatial distribution and can result in extreme amounts island-wide. In the year 2002, Guam experienced two typhoons – Chataan in July, and Pongsona in December – that each yielded 20 inches of rainfall in 24 hours over much of the island. The July typhoon produced short-term (one and three-hour) rainfall totals of 6.5 and 13 inches respectively that were near or over the 100-year return period.

To make accurate estimates of sustainable yield, groundwater hydrologists need to know the amount of water that infiltrates to the lens from the surface at slow enough rates for the lens to capture and retain it for sufficient time for it to be extracted by pumping.

The ultimate objective of this project was to develop a set of statistical models incorporating the key variables for predicting the recharge that is actually captured by various parts of the fresh water lens. A second objective was to gain a more thorough understanding of the long-term average rainfall distribution on Guam (complementing a companion project undertaken by WERI meteorologists). These objectives will provided baseline information for identifying deviations from the average distribution that have measurable impacts on the aquifer, and implications for a water management plan.

Methodology

We imported historical data into a spreadsheet program from which we graphed rainfall and well levels as a function of time at several different scales. Since 30-minute records were available for several USGS observation wells and rain gages and hourly data were available for NWS gages (and for target rain events from NEXRAD), we were able to resolve the rainfall intensity and well-level responses into hourly intervals, and daily means, as well as monthly, seasonal, and annual means. We selected specific wells and nearby rain gages for focused study. For several wells, the time lags of response to variations of rainfall were estimated. Data was also available to extend the analysis to years prior to and following previous periods of study. Also, data from some other wells not looked at in the original study were available for analysis.

Since there is a well-documented 50-year record of rainfall collected by the NWS and the Air Force for northern Guam and almost 20 years of hydrographic data from several USGS observation wells installed during the NGLS, we had ample data from which to work. The project PI and graduate student worked with NWS, Guam EPA, and USGS scientists, most specifically with the USGS Field Team in the Marianas, led by R. Carruth. Much of the data was transferred readily over the internet. With the help of Dr. Lander, the graduate student lead the statistical analysis of the wellhead and meteorological data.

Principal Findings and Significance

From the proposed study, we gained a further corroboration of the time lags at which water moves through, and is stored in the Northern Guam Lens Aquifer. Statistics and graphs from this project provided a means for inferring the proportion of water from a given storm that is actually captured in long-term storage by the lens and is thus available for extraction by pumping. We now have produced a set of statistical models that will predict, to a known degree of accuracy, the proportion of rainfall that is retained in short and long-term storage. Using this information, hydrologists will now be able to make wellhead predictions based on known rainfall variations and known storage parameters. The nearly two-year lag in the response of the wellheads to long-term surpluses and deficits of rainfall allow for long-term prediction of wellheads. These could be especially useful if rainfall variations due to EL Niño could be accurately anticipated (as they were in 1998 and again in 2002).

Results from this project have provided insight into how much recharge is associated with different weather phenomena on Guam – how much, for example, is contributed by local thunderstorms, monsoonal rains, tropical storms, and typhoons respectively. This improvement in our understanding of rainfall-recharge relationships has enabled us to make more accurate and precise estimates of recharge, and therefore sustainable yield, to be made for designated well fields and sectors of production in the aquifer. By gaining insight into how a given well responds to different intensities of rainfall, we can also infer the contribution of surface conditions, most especially the contributions of sinkholes, retention basins, and other natural and artificial surface features that modify infiltration rates. This understanding can now provide a basis for determining appropriate environmental and land use regulations and stormwater management practices over the aquifer.